1 np.

NASA TECHNICAL TRANSLATION NASA TT F-14,818

DUST STORMS ON MARS ACCORDING TO PHOTOMETRIC OBSERVATIONS TAKEN ON BOARD THE MARS-3 AUTOMATIC INTERPLANETARY STATION

V. I. Moroz, L. V. Ksanfomaliti, A. M. Kasatkin, and A. E. Nadzhip

Translation of "Pylevaya burya na Marse po fotometricheskim nablyudenyam s borta AMS 'Mars-3'," Kosmicheskiye Issledovaniya, Vol. 10, No. 6, 1972, pp. 925-929

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 FEBRUARY 1973

STANDARD TITLE PAGE

1. Report No.
NASA TT F-14,818

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
DUST STORMS ON MARS ACCORDING TO PHOTOMETRIC OBSERVATIONS TAKEN ON BOARD THE MARS-3 AUTOMATIC INTERPLANETARY STATION

5. Report Date
February 1973

6. Performing Organization Code

7. Author(s)
V. I. Moroz, L. V. Ksanfomaliti, A. M. Kasatkin, and A. E. Nadzhip

8. Performing Organization Report No.

9. Performing Organization Name and Address
Leo Kanner Associates
Redwood City, CA 94063

10. Work Unit No.

11. Contract or Grant No.
NASW-2481

13. Type of Report and Period Covered
Translation

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration, Washington, D.C. 20546

14. Sponsoring Agency Code

15. Supplementary Notes
Translation of "Pylevaya burya na Marse po fotometricheskim nablyudeniyam s borta AMS 'Mars-3-,'" Kosmicheskiye Issledovaniya, Vol. 10, No. 6, 1972, pp. 9251929

16. Abstract
Dust particle size estimates and dust cloud origins during dust storms on Mars are presented based on photometric profiles made of the planet by the Mars-3 Automatic Interplanetary Station. A particle size within the range 0.5-1 μm is held to best account for the scattering measurements in six narrow central spectral regions. Dust particle size may be as large as 10 μm in different regions of the same dust storm and in its different phases.

17. Key Words (Selected by Author(s))

18. Distribution Statement
Unclassified - Unlimited

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages
9

22. Price
3.00

I

DUST STORMS ON MARS ACCORDING TO PHOTOMETRIC OBSERVATIONS TAKEN ON BOARD THE MARS-3 AUTOMATIC INTERPLANETARY STATION /925*

V. I. Moroz, L. V. Ksanfomaliti,
A. M. Kasatkin, and A. E. Nadship

Certain parameters of dust storms on the 15 December and 27 December subsatellite tracks were estimated on the basis of photometric profiles of Mars obtained on board the Mars-3 artificial satellite in the wavelength range 0.3-1.4 μm during the dust storm. The mare-highland contrast as a function of wavelength is satisfactorily explained if a particle size of about 1 μm and an optical thickness of about 3 (for the 1.4 μm region) are assumed. Blue clouds were observed in the equatorial zone of the planet, probably related to scattering at finer (and more slowly settling) particles.

The Mars artificial satellites Mars-2 and Mars-3 went into orbit during a dust storm. Investigation of the planetary surface was thus hampered, but on the other hand it became possible to study the actual phenomenon of a dust storm at close range. In December and early in January observations were conducted under dust storm conditions, after which the dust settled. Comparison of measurements taken during these two periods affords several characteristics of the dust cloud layer formed in the Martian atmosphere during the "storm" period. The papers /1-3/ already discussed several of these measurements (temperature, cloud altitude, and H_2O content); here we wish to present the photometric profiles of Mars during the storm period and thereafter, and to give their preliminary interpretation.

---

* Numbers in the margin indicate pagination in the foreign text.

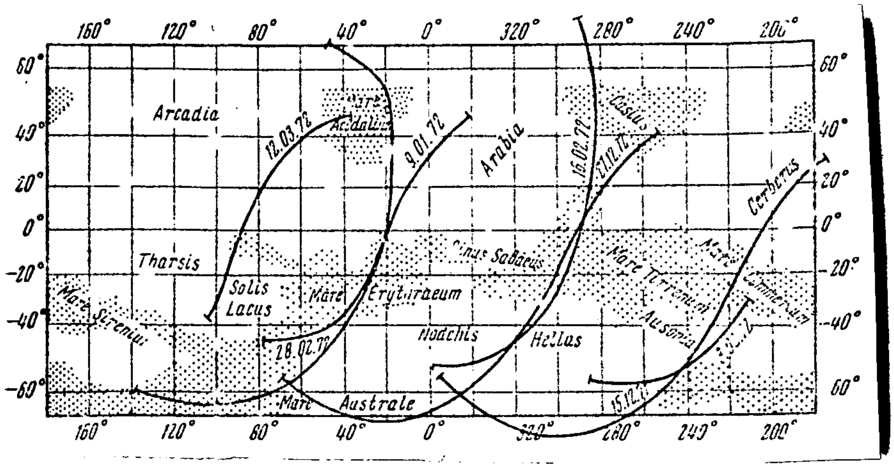

Fig. 1

As earlier, here we will discuss only the results obtained on Mars-3. Photometric profiles were obtained along the same tracks as for the main measurements; the tie-in of these tracks to the map of Mars is shown in Fig. 1.

The photometric profiles represent the relative distribu- /926
tion of brightness along the tracks of measurements in six narrow central regions. One of these, with the longest wavelength -- 1.3 μm, was recorded with a photometer in the H_2O band (the continuous spectrum channel) [3]; the remaining five were recorded in the 0.36-0.7 μm range with a photometer incorporating a photomultiplier. Fig. 2 shows the optical arrangement of this photometer. It has two operating regimes, alternating periodically. The planar mirror R_2 rotates continuously with a period of 36 sec. As this takes place, a field of view of about 120° in the scanning plane approximately coinciding with the orbital plane of the space craft is captured. The tubular collimator TC_1 directs the radiation through one of the three filters mounted in the disk FD_1 to the photomultiplier. The filters are switched once every 36 sec. The mirror R_2 remains in position 1 for 18 sec (while R_1 "looks" toward the planet); it is in position 2 during the next 18 sec, and the photomultiplier senses radiation through the collimator

TC_2 directed coaxially with the other photometric instruments. Here the radiation passes through one of the five filters not in the disk FD_2. This disk rotates continuously with a period of 1 sec. The wavelength and the half-width of the filters are given in the Table.

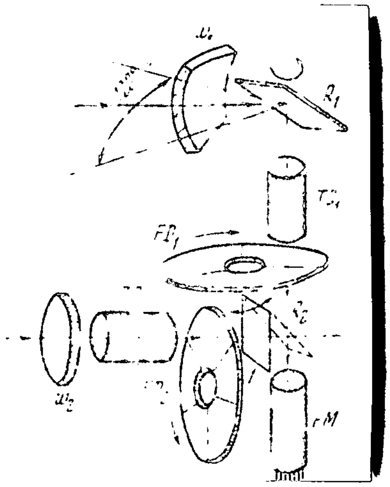

Fig. 2. Optical arrangement of the photometer in the spectral region 0.36-0.7 μm

All the filters are of the interference type, except for the shortest wavelength filter. The field of view of the tubular collimators is 0.03 rad (45 km at a distance of 1500 km).

Fig. 3.gives the photometric profiles along the 15 December 1971 track, obtained by the non-scanning channel. Plotted along the ordinate axis is the brightness B in an arbitrary linear scale. For comparison, Lambert's law ($B \propto \mu_1 = \cos z_0$) and the law for an optically thick layer of strongly absorbing particles ($B \propto \mu_1/(\mu_1 + \mu_2)$, where μ_2 is the cosine of the zenith angle of the AIS [Automatic Interplanetary Station]) are given for sake of comparison.

WAVELENTH OF PHOTOMETER FILTERS IN THE 0.37-0.7μm REGION

[illegible]		[illegible]	
λ, Å	$\Delta\lambda_{0.5}$, Å	λ, Å	$\Delta\lambda_{0.5}$, Å
6940	100	6940	110
4290	80	6520	[illegible]
3700	300	4940	[illegible]
		4160	[illegible]
		3700	[illegible]

[In Russian decimal number usage, commas are equivalent to periods in American practice]

Clearly, in the ultraviolet and blue spectral regions the law $\mu_1/(\mu_1 + \mu_2)$ closely describes the observations. The red and green profiles are not described by any of these two simplest approximations. The contour of Prometei Sinus was weakly discerned in the red profile, but Mare Cimmerium was completely undetectable.

Similarly, the profiles for 27 December in the red filter showed the already noticeable mare-highland contrast in the red filter for similar angles (Fig. 4, Iapigia), indicating a reduction in the optical thickness of the clouds in the equatorial zone of the planet. The ultraviolet profiles of 15 December and 27 December 1971 showed brightenings near the equatorial zone of the planet extending along the tracks for a distance of about 1000 km. We conditionally called them /927 ultraviolet clouds. Ultraviolet clouds were also observed on 9 January 1972; they were absent in the February tracks. Judging from all available data, during the dust storm the maximum optical thickness occurred precisely in the equatorial zone. It is possible that the ultraviolet brightening here, observed in the period of the last phase of the dust storm is attributable to the fact that the particles of submicron size responsible for scattering in the ultraviolet spectral region settled more slowly than other, coarser particles and formed the upper tier of the clouds. On the other hand, the condensation origin of these clouds cannot be precluded. They are especially visible in scans made with the ultraviolet filter.

Fig. 5 shows the photometric profile of Mars on the 15 December tracks in the 1.38 μm wavelength. The brightness of the highland regions is well approximated by Lambert's law (dashed line). Mare Cimmerium is clearly visible; the contrast is about 20 percent. From a comparison with Fig. 2 it is clear that the contrast between the dark and light regions in the

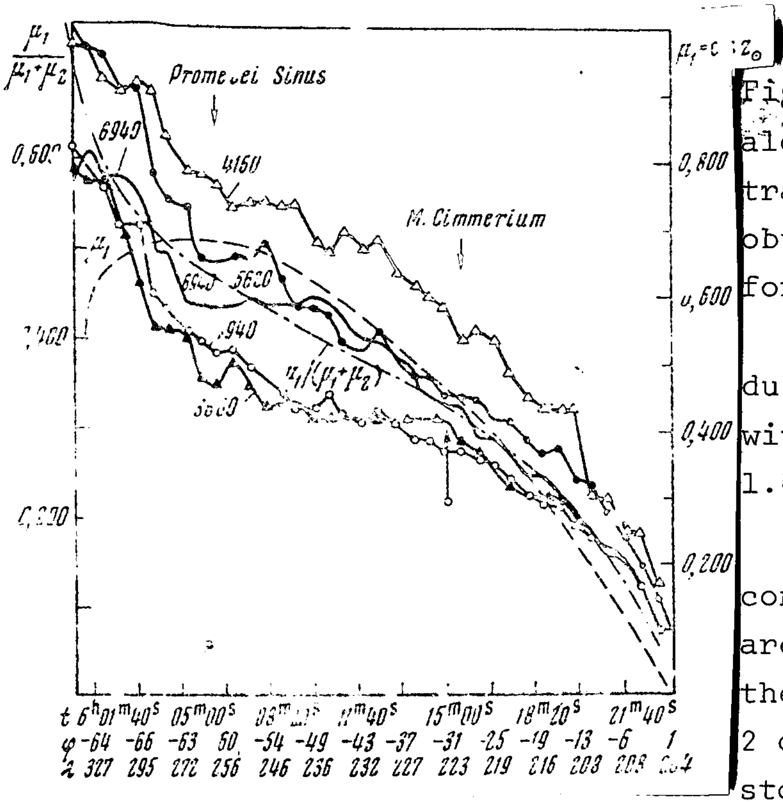

Fig. 3. Photometric profile along the 15 December 1971 track in five wavelengths, obtained with a photometer for 0.36-0.7 μm

dust period increases sharply with wavelength in the 0.7-1.4 μm range.

Still, near 1.4 μm the contrasts during the dust period are very much smoothed out. In the 28 February 1972 track (Fig. 2 of the paper [1]) after the storm they amounted to 50 percent. An old problem remains unresolved; why after settling of dust do the dark regions remain just as dark as before the storm. Here it must be stipulated that we do not have measurements with comparable three-dimensional resolution prior to the storms, but terrestrial observations give us mare-highland contrast in this spectral region that are similar in magnitude to contrasts measured after the storm. There are few highland regions in this profile, but the brightness of those that are observed is satisfactorily approximated by Lambert's law. As far as we can judge from available material, the brightness coefficients of the highlands after the storm were reduced by 20-30 percent at the wavelength of 1.38 μm. The northern polar cap is completely undetectable in the 1.38 μm photometric profile, though its margins are well delineated in the visible spectral region. Obviously, the observed part of the polar cap is atmospheric haze of very fine particles and not a sediment lying on the surface. Why the mare-highland contrast markedly increases (cf. Fig. 3) in passing from the wavelength

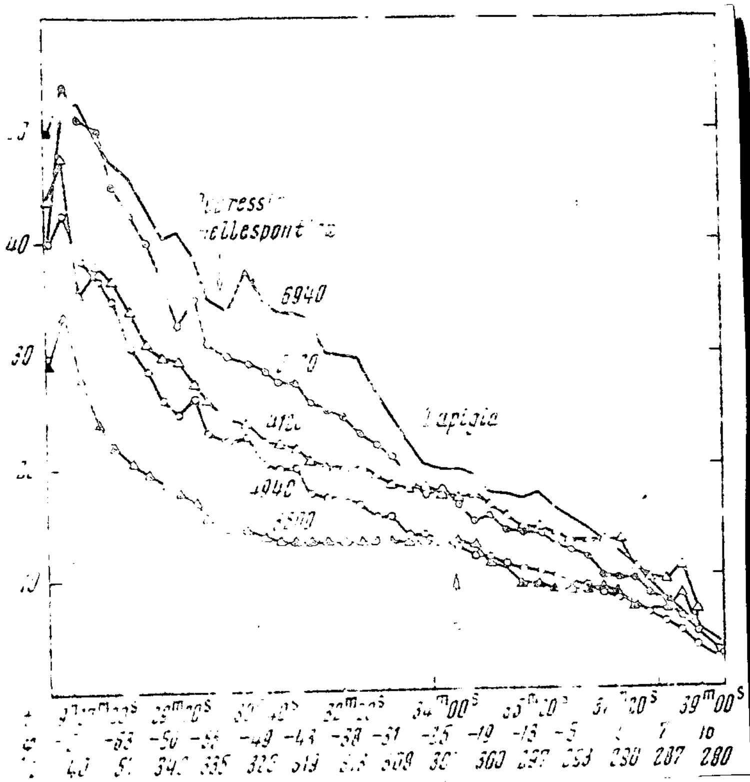

Fig. 4. As above in Fig. 2, along the 27 December 1971 track /928

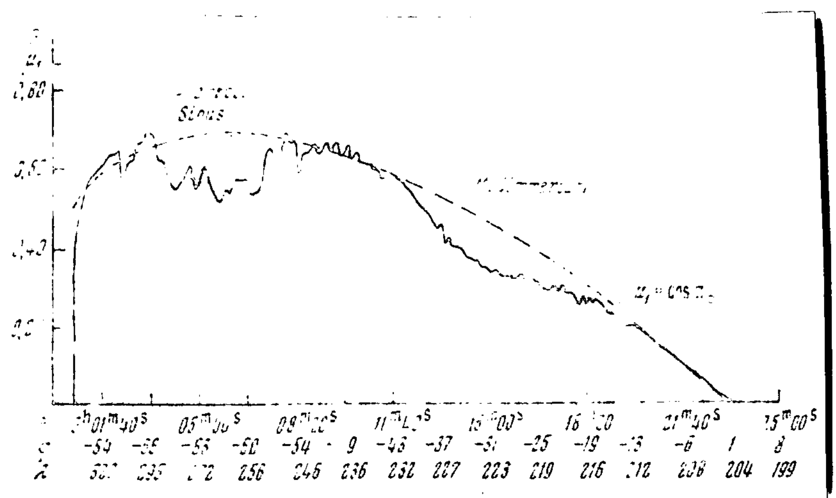

Fig. 5. Photometric profile along the 15 December 1971 track in the wavelength 1.38 μm

5620 to 6940 Å is understandable -- here true absorption decreases rapidly. However, an increase in contrast from 0.7 to 1.3 μm can scarcely be explained in this manner. Actually, the albedo of Mars in this range changes little; the material of the dust storm particles and the highlands is identical. Therefore, the coefficient of particle absorption should not vary widely. Another explanation is more probable: in the neighborhood of 1.38 μm the scattering effectiveness and the optical thickness τ in scattering are less due to the small particle radius. We must assume a radius /929

$$0.5 < r < 1 \ \mu m \tag{1}$$

for $\tau \simeq 3$ in order to obtain a contrast of about 20 percent in the vicinity of 1.4 μm. The optical thickness near 0.7 μm will be greater than 6 in this case and the contrast will be less than 10 percent. Our estimates were made using the approximational scattering theory in thick layers developed by G. V. Rozenberg [4]. It was assumed that the ratio of the absorption and scattering coefficients in both wavelengths is 0.04. The result is not critical to the selection of this value.

The estimate (1) agrees with the small optical thickness in the 8-40 μm range, though here observations can be explained by the coarser particles, if they are transparent. Some American workers [5] maintain that a large fraction of the particles have dimensions of about 10 μm, otherwise it is difficult to explain the rapid clearing in the second half of December. This contradicts estimate (1). It is most probable that both points of view are correct: the particle size spectrum is broad and can be different in different regions of Mars and even in the same region at different altitudes, since the settling rate depends on size. Earlier estimates were made of particle size by equating the settling time for a given radius to the total duration of a dust storm. A radius of about 1 μm was also obtained in this way [6], but it is clear that this is only the lower limit, since the absence of vertical movements was assumed. If the mean particle radius is actually about 1 μm, as we suggest, the agreement of estimates obtained by both methods signifies that vertical movements actually are weak and that the dust storm is not a "storm" in the common sense of the word, at least during the protracted last phase. It is probable that the storm begins with an active phase when strong winds build up and the highland dust is lifted to great altitudes and ends with a quiescent settling phase. Of course, it is not precluded that peaks of activity can be repeated several times during a storm.

The altitude to which particles are ejected during a dust storm can be 10 km and higher [2,7].

The temporary cloud layer which is formed during a dust storm is much more transparent for planetary radiation in the 8-40 μm range [1,8] than for solar radiation in the 0.3-1.5 μm range. This, as already noted (1), leads to the unusual phenomenon of the "anti-greenhouse effect": the surface becomes colder and the atmosphere warmer than in ordinary conditions.

Received
28 June 1972

REFERENCES

1. Moroz, V. I., Ksanfomaliti, L. V., Kasatkin, A. M., Krasovskiy, G. I., Parfent'yev, N. A., Davydov, V. D., and Fillipov, G. F., Dokl. AN SSSR 208, No. 2 (1973).

2. Moroz, V. I., Ksanfomaliti, L. V., Kasatkin, A. M., Kupashev, B. S., and Tsoy, K. A., Dokl. AN SSSR 208, No. 4 (1973).

3. Moroz, V. I., Nadzhip, A. E., Gil'varg, A. B., Korolev, F. A., and Zhegulev, V. S., Dokl. AN SSSR 208, No. 3 (1973).

4. Rozenberg, G. V., Dokl. AN SSSR 145: 775 (1972).

5. Burgness, E., New Scientist, 24 Feb 1972.

6. Morozhenko, V. A., Astron. tsirk., No. 683 (1972).

7. Kliore, A. J., Cain, D. A., Fjeldbo, G., Seidel, B. L., and Rasool, S. I., Science 175: 313 (1972).

8. Chase, S. C., Jr., Hatzenbeler, H., Kieffer, H. H., Miner, E., Munch, G., and Neugebauer, G., Science 175: 309 (1972).

4

9